sunflower population, row width, and row direction

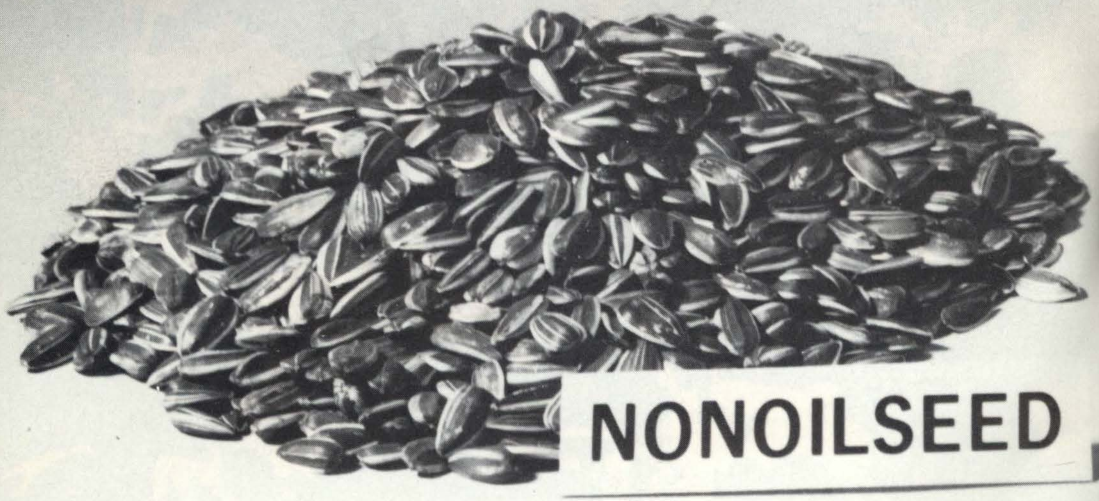
miscellaneous report 141 — 1976 agricultural experiment station university of minnesota

preface

Sunflowers are grown in Minnesota for oilseed, human food, and birdfeed. Oilseed varieties are used for extraction of oil and protein. Nonoilseed varieties are used for birdfeed, roasting whole seed for human food, or dehulling for nutmeats.

Oilseed varieties generally have small, black seed; nonoilseed varieties generally have large, striped seed. Planting rates of oilseed varieties often exceed those of nonoilseed varieties by nearly 10,000 seeds per acre. Even so, more pounds per acre of nonoilseed seeds must be planted because of their larger size and weight. Most users of nonoilseed varieties suggest low plant populations to reduce seed costs and to produce crops of large seed.

This report summarizes world-wide research on plant populations, row widths, and row directions and gives Minnesota research data and conclusions.



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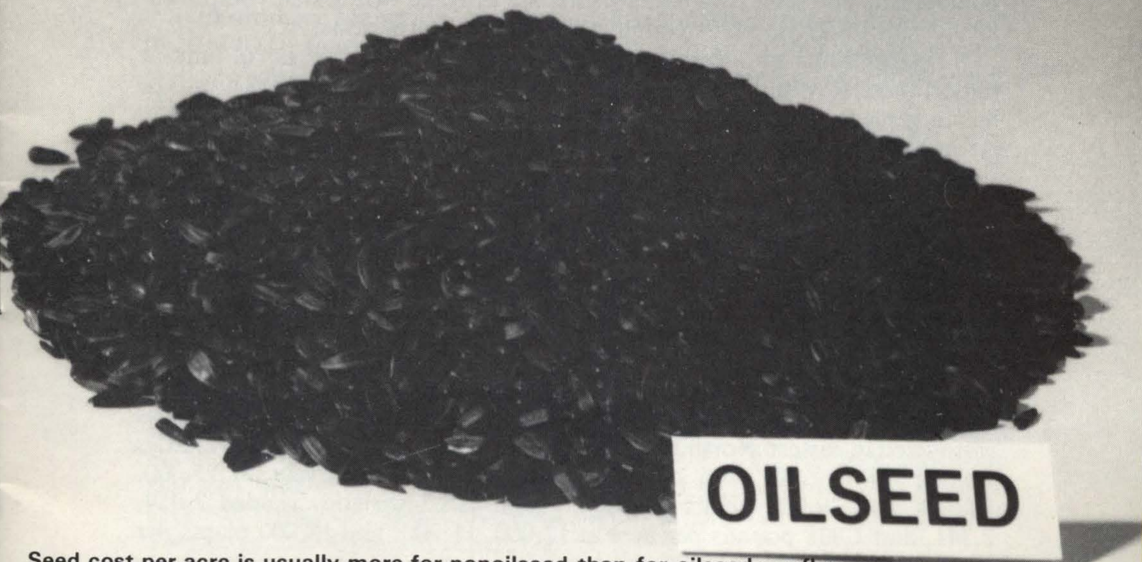

Seed cost per acre is usually more for nonoilseed than for oilseed sunflowers. Both piles of seed weigh 1 pound, but there are 3,700 seeds in the nonoilseed pile (left) and 11,000 seeds in the oilseed pile (right).

sunflower population, row width, and row direction

R.G. Robinson, D.L. Rabas, L.J. Smith, D.D. Warnes, J.H. Ford, and W.E. Lueschen

Sunflowers are grown for their seed. The three components of seed yield are number of heads per acre, number of seeds per head, and average seed weight. The product of these three components is yield per acre.

Since most sunflower varieties produce one head per plant, the first component of yield — number of heads per acre — is determined by plant population. The other two components are affected by the first component and by sunflower variety, weather, soil, and sunflower pests.

Distribution or arrangement of plant population is of major importance. Possibilities range from clumping many plants in a group to locating plants singly and at an equal distance from neighboring plants. Arrangement of the population is altered by varying row width, by planting seeds in groups, or by changing row direction.

review of previous research

Disagreement as to optimum plant population is a common occurrence. Differences within a region are as great as those between different countries of the world.

High populations may be needed for highest yields according to results of eight trials with oilseed varieties and seven trials with nonoilseed varieties conducted in eastern North Dakota from 1971 to 1974 (16). Oilseed varieties yielded 1,944, 2,275, and 2,777 pounds per acre, respectively, at 15,000, 19,000, and 29,000 plants per acre. Nonoilseed varieties yielded 2,054, 2,341, and 2,838 pounds per acre at 12,000, 15,000, and 19,000 plants per

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R.G. Robinson is a professor, Department of Agronomy and Plant Genetics. D.L. Rabas, L.J. Smith, D.D. Warnes, J.H. Ford, and W.E. Lueschen are agronomists at the North Central, Northwest, West Central, Southwest, and Southern Experiment Stations, respectively.

acre, respectively. But plant population differences had little effect on yield at Fargo in 1971 and 1972 and at Crookston, Minnesota in 1972 and 1973. There was no significant difference in yields of nonoilseed varieties at 10,000, 15,000, or 29,000 plants per acre at Fargo (13). At Crookston, populations of 10,000, 15,000, or 20,000 did not affect yield of nonoilseed varieties nor did populations of 20,000, 25,000, or 30,000 plants cause differing yields of oilseed varieties (12).

Trials on silt loam soil at Rosemount, Minnesota in 1955-56 with populations of 9,000, 13,000, and 26,000 plants per acre resulted in yields of 848, 1,046, and 1,257 pounds per acre, respectively. In 1967, sunflowers in populations of 21,000, 35,000, and 47,000 did not differ significantly in yield and produced 1,868, 1,996, and 1,935 pounds per acre, respectively. But both lodging and seed-oil percentage were lowest in the 21,000 population. Yields of 2,320, 2,197, and 1,935 pounds per acre were obtained from sunflowers grown in rows 12, 24, and 36 inches apart, respectively, but populations were greatest in 12-inch and least in 36-inch rows despite an equal planting rate. Row width did not affect lodging. In 1968, sunflowers grown in populations of 18,000, 30,000, or 42,000 in 36-inch rows, 28,000 or 47,000 in 24-inch rows, or 57,000 in 12-inch rows did not differ significantly in yield. But oil percentage increased and large seed percentage decreased as population increased.

On sandy soil at Elk River in 1968 and 1969, sunflowers in populations of 25,000 plants yielded significantly more on both irrigated and dryland plots than did those grown in 43,000 populations. Trials on sandy soil at Grand Rapids in 1968 and 1969 showed no significant yield differences among sunflowers grown in 20,000 and 25,000 populations in 36-inch rows; 27,000 and 34,000 in 24-inch rows; or 45,000 in 12-inch rows.

In southern Manitoba, optimum plant populations ranged from 23,000 to 26,000 (1). In earlier research, 29,000 plants in rows 36 inches apart gave highest yields, but in rows 18 inches apart, 19,000 plants gave highest yields (6).

In Saskatchewan and India, populations of 24,000 to 30,000 were recommended (14). In India, yields increased as population increased from 8,000 to 27,000 and then decreased as population increased from 27,000 to 84,000. In Saskatchewan, populations of 10,000 and 30,000 did not differ in yield nor did sunflowers in rows 14, 21, or 35 inches apart. But in these trials, yields were only 500 to 1,300 pounds per acre, and drought was the major limiting factor.

In Georgia, sunflowers in a 24,000 population yielded much more than those in populations of 8,000 or 12,000 (4). Other trials in Georgia showed no yield differences among populations between 10,000 and 29,000 (2). Lowest yields occurred at 58,000. But in these latter trials, yields averaged about 1,000 pounds per acre, and such low yields from research plots suggest that factors other than population limited yields. In California under sprinkler irrigation, yields increased slightly as population decreased from 174,000 to 22,000 plants per acre (3).

Research from Europe also shows inconsistent results, but populations of 16,000 to 20,000 were frequently highest in yield.

Sunflowers planted in rows 6 to 12 inches apart do not need cultivation if early emerging weeds are controlled with preplant or preemergence herbicides. However, it is difficult to get uniform seed distribution of recommended populations with a grain drill. And at high populations, lodging in wet years and poor growth in dry years are hazards.

Some acreage in Canada is planted with a grain drill or disker in narrow rows 12 to 16 inches apart. Recommended plant populations are 25,000 (7) to 35,000 plants per acre.

In dryland areas of Canada and North Dakota where a year of fallow is used to store soil moisture, some sunflowers are grown in single or double rows 10 to 18 feet apart instead of fallow. In research plots, rows 12 feet apart produced slightly over half as much as did rows 3 feet apart. Plant spacings of 3 to 4 inches apart are recommended for these wide rows (7).

Single-plant spacing rather than clumps of two or more plants gave highest yields at Rosemount in both 13,000 and 26,000 plant populations (8). Single-plant spacing was also best in Manitoba in 18-inch rows. But in 36- by 36-inch spacings to allow cross-cultivation, 5- to 9-plant hills were needed because 1- to 3-plant hills gave too low a population (6).

conclusions from previous research

Sunflowers can yield well through a wide range of populations and plant arrangements. Contrary to experience with corn, there was no pattern of high populations being best for high-rainfall areas and low populations for arid areas or sandy soils.

Differing environments may account for some of the conflicting data. Much of the population research was based on thinning thickly-planted rows to the populations desired rather than planting to exact spacing. In many of the trials, yields were so low (for research plots) that factors other than population were strongly limiting yield. Consequently, even the lowest population was capable of producing the highest yield.

Very little research has been reported on arrangement of population using row widths that are practical for cultivation in Minnesota and on row direction.

population and row width trials from 1971 to 1975 in minnesota

These trials compared sunflower populations of 15,000, 20,000, 25,000, 30,000, and 35,000 plants per acre each grown in three row widths — 22, 30, and 38 inches apart. The five populations included the full range of populations recommended in Minnesota (8). The 22-inch row width is commonly used by sunflower growers who also raise sugarbeets and the 30- and 38-inch widths by those who grow corn or soybeans. Trials were located on silt loam and clay soils of high water-storage capacity at Waseca, Lamberton, Morris and Crookston and on sandy soil at Grand Rapids.

Sixteen row widths varying from 14 to 40 inches were compared on sandy soil at Elk River and on silt loam at Rosemount. The sand at Elk River is 1 to 2 feet deep, underlaid with gravel, and the silt loam at Rosemount is 3 to 3.5 feet deep, underlaid by sand. Consequently, drought is usually a major factor at Elk River all season and at Rosemount for shorter periods during July and August.

experimental details

The experimental design was a split plot with row widths as main plots replicated four times and populations as subplots. Each subplot was three rows by 20 feet long. Rows were marked in the seedbeds with 22-, 30-, or 38-inch row markers pulled by hand. Three to five seeds were planted by hand alongside poles marked to indicate the proper spacing for each population. Plants were thinned to one plant per spot when they reached the cotyledon to two-leaf stage. The only plants harvested for yield were those in the center row of each plot and that were surrounded by perfect stands of the desired spacing. Yields were based on the exact space occupied by the harvested plants.

Grain drill planting of sunflowers shows uneven stand even at a high population.

Varieties used were Sundak nonoilseed variety in 1975, USDA 896 oilseed hybrid in 1974, Sputnik oilseed variety in 1973, and P-21 ms X HA60 oilseed and birdfeed hybrid in 1971 and 1972.

An unusual planting arrangement was used to compare the 16 row widths at Elk River and Rosemount. A 20-foot long compass constructed of angle iron was used to draw circles of 40-feet diameter on the seedbeds. Straight lines drawn from the center of a circle to points 10 degrees apart on its circumference marked 36 "wheel-spokes". Seeds were hand-planted at each of 18 points along each spoke starting 4.8 feet from the center of the circle and ending at 19.5 feet. Seed spacing along each spoke was greatest at the center and decreased to the outside so that the area occupied by each plant halfway to its neighbors was .00004167 acre (24,000 plants per acre). A circle of Sputnik oilseed variety and one of Sundak nonoilseed variety was planted at each location. A row-width plot consisted of 18 plants harvested at the same distance from the center of the circle in a 180 degree arc. Thus two replicates (2 x 180° = 360°) of each row width were harvested from each circle. The inner and outer row-width plots were borders except at Elk River where noticeable border effects on the droughty soil required three outer borders.

All trials were fertilized before planting with 60 to 100 pounds nitrogen per acre, unless soil tests indicated about 100 pounds were already present. Plots were kept weed-free by either trifluralin or EPTC sprayed before seedbed preparation, chloramben applied preemergence, and hand weeding.

population comparisons and seed requirements

Yields from the five populations at four locations are shown in table 1. In all 4 years of trial at Waseca, yields increased as population increased from 15,000 to 35,000. Sunflowers in the 35,000 populations yielded from 3,821 to 4,530 pounds per acre during the 4 years.

A sunflower "wheel" with spokes for row-width research.

Table 1. Seed yields from sunflower populations of 15,000, 20,000, 25,000, 30,000, and 35,000 plants per acre

	Oilseed Varieties					Nonoilseed Variety	
Population	Waseca 1971-74	Lamberton 1973-74	Morris 1972-74	Grand Rapids 1972-74	Average 12 trials	Morris 1975	Grand Rapids 1975
15,000	2,731	1,942	2,239	1,326	2,024	1,419	1,638
20,000	3,161	2,066	2,305	1,384	2,163	1,511	1,623
25,000	3,360	1,969	2,338	1,337	2,195	1,494	1,917
30,000	3,640	1,893	2,317	1,197	2,196	1,519	1,697
35,000	4,115	1,896	2,344	—	—	1,543	—
LSD 5%	220	155	224	156	110	218	231

In contrast with these strong effects of population at Waseca, population did not affect yield at Morris or Lamberton. The only exception was in 1974 at Lamberton where the 35,000 population yielded significantly less than the other populations. At Grand Rapids, population affected yield in 2 of the 4 years; and 30,000 plants tended to be excessive. At the latter three locations, populations above 15,000 gave no significant yield advantage on the average. However, there was no yield reduction from populations up to 25,000.

The effects of population on yield in the differing row widths of 22, 30, and 38 inches were similar. In the 14 trials, the only instance where the interaction of population with row width reached significance was at Morris in 1975. But the differences did not fit a logical pattern, and if considered with all trials can be attributed to normal variability.

Yields and the differing effects of population on yield among the four locations may be attributed to soil, temperature, and rainfall (table 2). Trials at Lamberton, Waseca, and Morris were on silt loam soils with fine-textured subsoils. The much lower rainfall and slightly higher temperatures at Lamberton resulted in lower yields and no advantage from high populations. Although yields and rainfall were higher at Morris than at Lamberton, yields were lower than at Waseca and not sufficiently high to show an advantage for high populations. The low temperatures and high rainfall at Grand Rapids resulted in satisfactory yields despite the low moisture storage capacity of the sandy soils.

Population had important effects on both market quality and agronomic characteristics (tables 3, 4). In 13 of the 14 trials, there was a

Table 2. Average temperature and total precipitation during June, July, and August at Waseca, Lamberton, Morris, Grand Rapids, Rosemount and Elk River

Year	Waseca	Lamberton	Morris	Grand Rapids	Rosemount	Elk River
			temperature, °F			
1971	69	—	—	—	69	—
1972	67	—	68	64	68	—
1973	70	71	70	66	71	68
1974	68	70	67	65	69	—
1975	—	—	69	66	71	—
			rainfall, inches			
1971	2.9	—	—	—	4.2	—
1972	3.7	—	3.4	3.6	4.9	—
1973	4.6	1.6	2.8	3.7	3.9	9.9
1974	4.0	1.8	3.7	4.1	3.6	—
1975	—	—	4.4	3.1	5.0	—

Table 3. Average of 12 trials for seed oil percentage, seed size and weight, seed test weight, seed number per head, stalk lodging, plant height, and flowering date of oilseed varieties grown in five populations at Waseca, Lamberton, Morris, and Grand Rapids

Population	Oil* (percent)	Large seed** (percent)	Weight/ 100 seeds (grams)	Test weight/ bushel (pounds)	Seeds/ head (number)	Lodging† (score)	Height (inches)	Flowering (date)
15,000	42.6	46	7.3	29.9	831	1.5	74	August 1
20,000	43.2	35	6.7	30.4	727	1.8	76	August 1
25,000	43.2	29	6.2	30.2	632	2.1	76	August 1
30,000	43.4	24	6.0	30.5	548	2.4	76	July 31
35,000††	43.8	20	5.8	30.5	501	2.5	76	August 1
LSD 5%	0.6	1	0.2	0.4	—	0.2	1	1

*Oven-dry basis.

**Held on 14/64 or 16/64 round-hole screen.

†1 erect, 9 flat.

††No 35,000 population at Grand Rapids, but average data are adjusted to be comparable with the other populations.

Table 4. Average of trials at Morris and Grand Rapids for seed oil percentage, seed size and weight, seed test weight, seed number per head, stalk lodging, plant height, and flowering date for Sundak nonoilseed variety grown in five populations

Population	Oil* (percent)	Large seed** (percent)	Weight/ 100 seeds (grams)	Test weight/ bushel (pounds)	Seeds/ head (number)	Lodging† (score)	Height (inches)	Flowering (date)
15,000	27.4	52	12.5	25.4	373	1.6	71	August 4
20,000	28.3	44	11.5	25.9	310	2.0	72	August 3
25,000	28.8	33	11.1	26.0	281	2.3	73	August 3
30,000	28.8	31	10.7	25.9	229	2.4	73	August 3
35,000††	29.6	26	10.1	27.0	222	2.7	73	August 3
LSD 5%	0.8	8	0.4	0.6	—	0.3	1	1

*Oven-dry basis.
**Held on 20/64 round-hole screen.
†1 erect, 9 flat.
††No 35,000 population at Grand Rapids, but average data are adjusted to be comparable with other populations.

noticeable trend for oil percentage to increase with population. And in four of the trials and on the average, differences were significant. In three of the 14 trials and on the average, test weight differences were significant and tended to increase with population, but the trend was not as consistent as that for oil percentage. In 11 trials, seed from the 15,000 population was lowest in test weight and seed from 30,000 or 35,000 populations was highest.

The characteristics most affected by population were seed size and seeds per head (tables 3, 4). Large seed percentage, weight per 100 seeds, and seeds per head decreased as population increased in all trials, and most differences were highly significant.

Lodging increased as population increased and differences were significant in 9 of 11 trials (tables 3, 4). These trials were harvested by hand, so lodging did not cause harvesting losses. However, yield losses, if any, resulting from lodging effects on photosynthesis or translocation were possible. Population effects on height and flowering date were not agronomically important.

The relative performance among populations for the characteristics in tables 3 and 4 was similar within 22-, 30-, and 38-inch rows. Significant interactions of population with row width occurred, but these exceptions did not occur in more than two trials for any characteristic, were of small magnitude, and were not in important conflict with the general trend.

Lodging resulting from excessive population is evident in this 70 acre field of sunflowers in the Red River Valley. Despite a population of 50-thousand plants per acre, the yield was 1,300 pounds per acre. An adjacent field with 25-thousand plants per acre did not lodge and yielded 1,800 pounds per acre.

Sunflowers adjusted to low populations by increasing seed weight and number of seeds per head and to high populations by decreasing seed weight and seeds per head. So, yield which is the product of plant population, weight per seed, and number of seeds per head remained relatively constant through a wide range of populations. But, in environments where yields approached the yield capacity of the variety, adjustments among components of yield were not sufficient. Consequently, population differences affected yields at Waseca where the lowest yield was 2,731 pounds from 15,000 plants. Yields did not approach this level at any other location, so 15,000 plants were enough for maximum yields except at Waseca.

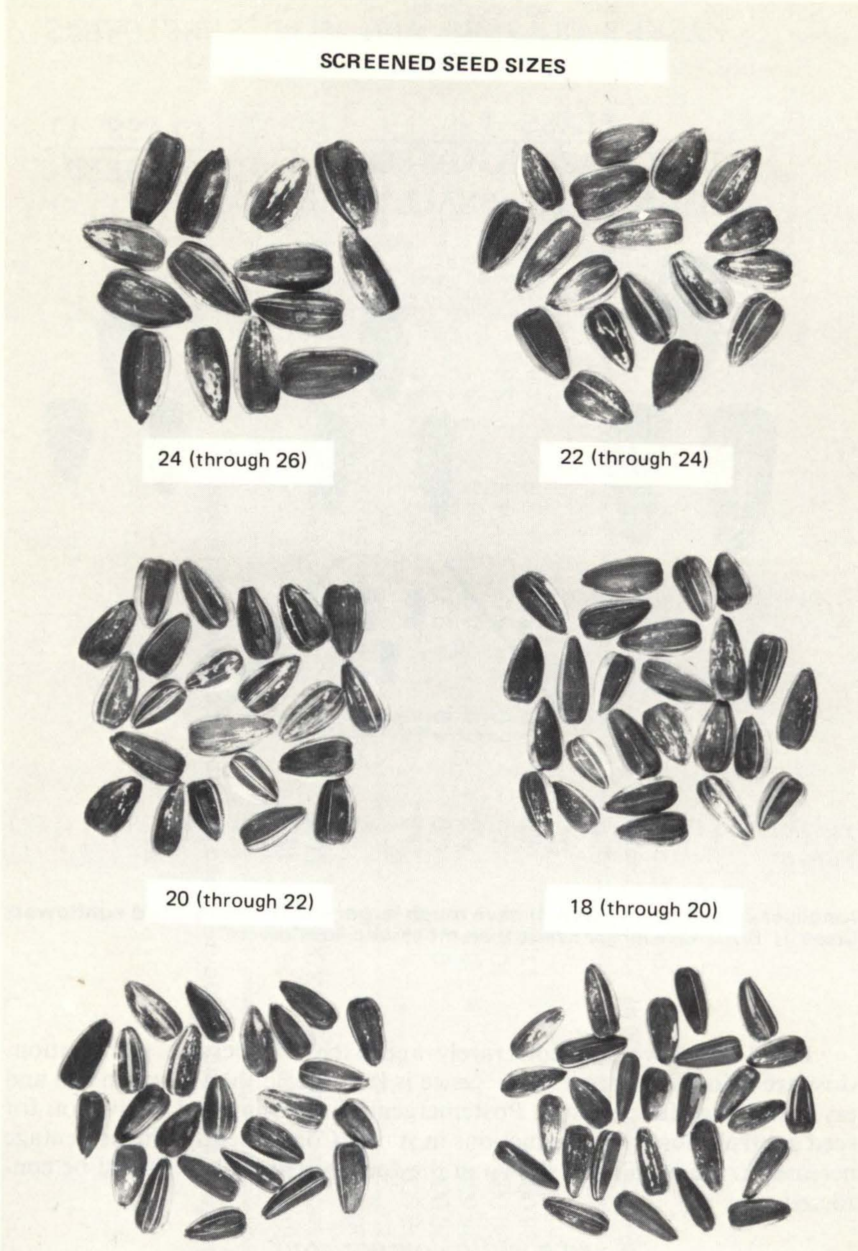
High populations offer the advantage of small heads that remain upright and dry faster than large heads. Head size was satisfactory in all populations except at Waseca where heads in the low populations were very large and dried slowly.

Lowest oil yields per acre and largest seeds were obtained from the 15,000 populations at all locations. Consequently, seed from 15,000 populations is excellent for dehulled and whole seed food markets, but higher populations are suggested for oilseed production.

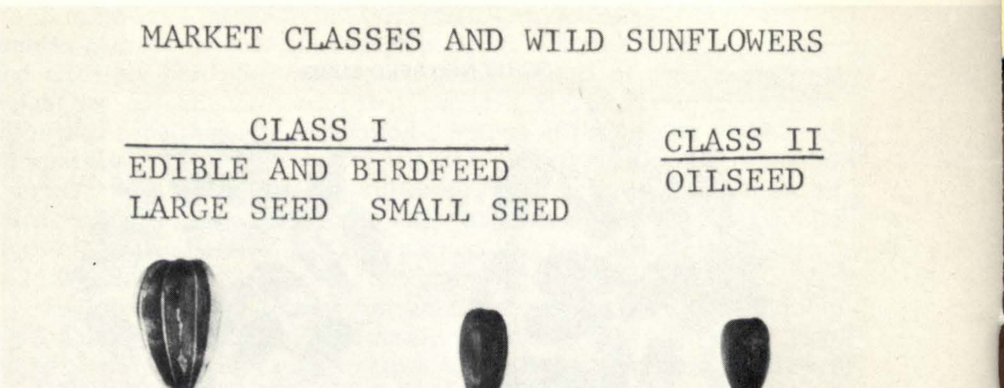
Minnesota's average sunflower yields from 1967 to 1975 were 1,069 pounds per acre for oilseed and 922 for nonoilseed production. This consistent yield difference is not due to greater yielding ability of oilseed varieties. All varieties were tested in Minnesota Agricultural Experiment Station trials, and the commonly grown oilseed varieties were not higher yielding than the nonoilseed varieties (10). Planting rates of oilseed varieties often exceed those of nonoilseed varieties by nearly 10,000 seeds per acre. Emergence failures and plant mortality are less likely to reduce yield in high than in minimum populations. A plant in a 30,000 population with a single gap on each side is still at a 15,000 population, but a plant with a gap on each side in a 15,000 population is left in only a 7,500 population. Greater plant populations, and perhaps differing areas of production probably account for the higher state average yield from oilseed production.

Seed of oilseed varieties generally weighs less than half that of nonoilseed varieties, so fewer pounds are needed to achieve a desired population (table 5). Until 1974, seed cost per acre was low relative to other crops, but expensive hybrid seed has made seed cost important in choosing a planting rate.

One way of reducing seed cost is to use the smallest *good* seed grade of the desired variety. Crops produced from large, medium, or small seed sieved from ungraded seedlots did not differ in yield, oil percentage, or test weight (9). A "trash" grade of small, lightweight seed comprising 2 percent of the ungraded seedlot produced plants of low seedling vigor and 22 percent lower yield than plants of ungraded seed at the same population. This research used seedlots from oilseed, birdfeed, and human food varieties. Crops produced from large seed had larger seed than crops from small seed. But seed size is effectively controlled by plant population, and the size of seed planted is not of practical importance. On the average, use of small and medium seed resulted in savings over large seed of 36 and 16 percent, respectively.



These different seed sizes were screened from a single seedlot. Crops produced from these various sizes will not differ in yield.



Nonoilseed sunflowers (Class I) have much larger seeds than oilseed sunflowers (Class II). Both have larger seeds than most wild sunflowers.

Good sunflower seedlots rarely approach 100 percent germination. Most are below 95 percent. Emergence is less in cold than in warm soil and less in clay than in loam soil. Postemergence harrowing and cultivation for weed control cause slight reductions in stand. Consequently, the percentage increases in planting rates shown in the footnote of table 5 should be considered.

row width comparisons

Sunflowers grown in rows 22-, 30-, or 38-inches apart did not differ significantly in seed yield, oil percentage, seed size or weight, seed test weight, seeds per head, height, or flowering date (tables 6, 7). These results were consistent among trials. The only exceptions were of small magnitude

Table 5. Guide to seed requirements based on population and seed weight

Weight per 100 seeds (grams)	15.1	11.3	9.1	7.6	6.5	5.7	5.0	4.5	4.1
Number of seeds per pound	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000
Population desired	Seed required per acre (pounds)*								
15,000	5.0	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4
20,000	6.7	5.0	4.0	3.3	2.9	2.5	2.2	2.0	1.8
25,000	8.3	6.3	5.0	4.2	3.6	3.1	2.8	2.5	2.3
30,000	10.0	7.5	6.0	5.0	4.3	3.8	3.3	3.0	2.7
35,000	11.7	8.8	7.0	5.8	5.0	4.4	3.9	3.5	3.2

*To allow for seed and young plant mortality, increase by 5 percent on sandy soils and up to 20 percent on other soils, and increase for less than 100 percent germination by: $\frac{\text{Pounds/acre times 100}}{\text{percent germination}}$

Table 6. Average yield, seed oil percentage, seed size and weight, seed test weight, seed number per head, stalk lodging, plant height, and flowering date of oilseed varieties grown in three row-widths and five populations at Waseca, Lamberton, Morris, and Grand Rapids in 1973-74

Row width (inches)	Seed yield/acre (pounds)	Oil* (percent)	Large seed** (percent)	Weight/ 100 seeds (grams)	Test weight/ bushel (pounds)	Seeds/ head (number)	Lodging† (score)	Height (inches)	Flowering (July)
22	2,280	47.6	39	6.8	30.6	617	1.6	74	29
30	2,255	47.3	39	6.9	30.6	601	2.1	73	29
38	2,286	47.1	40	6.9	30.4	612	2.4	74	29
LSD 5%	153	1.0	3	0.1	0.4	—	0.2	2	0.3

*Oven-dry basis. **Held on 14/64 or 16/64 round-hole screen. †1 erect, 9 flat.

Table 7. Average yield, seed oil percentage, seed size and weight, seed test weight, seed number per head, stalk lodging, plant height, and flowering date of Sundak nonoilseed variety grown in three row-widths and five populations at Morris and Grand Rapids in 1975

Row width (inches)	Seed yield/acre (pounds)	Oil* (percent)	Large seed** (percent)	Weight/ 100 seeds (grams)	Test weight/ bushel (pounds)	Seeds/ head (number)	Lodging† (score)	Height (inches)	Flowering (July)
22	1,635	28.5	36	11.2	26.1	284	1.5	71	4
30	1,628	28.4	40	11.3	25.6	280	2.2	72	3
38	1,561	28.5	40	11.5	26.0	262	2.8	72	3
LSD 5%	343	1.1	7	0.3	0.5	—	0.2	1	1

*Oven-dry basis. **Held on 20/64 round-hole screen. †1 erect, 9 flat.

Insufficient competition from nearby plants causes heads in low populations and at the ends of rows to be large. Large heads dry slowly, but use of preharvest dessicants may reduce that disadvantage of large heads.

and occurred at Morris in 1974, when 22-inch rows produced the smallest seed of highest test weight and oil, and at Grand Rapids in 1973, when 22-inch rows produced the largest seed and tallest plants of latest bloom.

The interactions of row width with population were generally not significant. Consequently, the row-width data in tables 6 and 7 are the averages of five populations.

Width of row significantly affected lodging in all trials where lodging occurred. Lodging was greatest in 38-inch and least in 22-inch rows. At equal populations, plants are closer together in wide than in narrow rows (table 8).

Row widths compared in circular plantings at Rosemount and Elk River ranged between 14 and 40 inches and did not differ significantly in yield, oil percentage, or seed size (table 9). These results are in agreement with those from the normal rectangular plantings at the other locations. Many row widths can be evaluated in minimum space by using this circular planting technique. Consequently, trends in yield and other characteristics can be detected that might not be apparent in the usual experiment involving only a few widths of row. But lodging differences among row widths cannot be evaluated in circular plantings because of lack of border plants.

The basal stem rot disease caused by *Sclerotinia sclerotiorum* (Lib.) de Bary spreads by root contact (15). Wide spacings between plants delay this contact. Because plants within 22-inch rows are farther apart than in 38-inch rows, narrow-row plantings might show less damage than 38-inch rows in some environments. Severe damage (lodging) from *Sclerotinia* has occurred in sunflower plots planted at high populations in uncultivated rows 6 and 12 inches apart.

row direction

Sunflowers are phototropic from emergence through flowering. The head and leaves face east in the morning and west in the evening. After the ray-flowers are fully developed, phototropic movement ceases and most heads face the east. When sunflowers were harvested by hand, some growers of tall varieties preferred north-south rows because heads overhanging a wagon pulled along the east side of the row could be easily gathered. Now, shape and slope of the field are the only factors considered in choosing row direction.

Few scientific attempts have been made to measure the effect of row direction on crop yields because of the inconvenient plot arrangements and large amount of space required. The large plots needed to avoid border effects usually require large turning areas for farm machinery, and replications are needed.

Unlike the phototropic sunflower, most field crops in Minnesota do not have a directionally-oriented morphology. Exceptions are the roots of some wheat varieties that orient north-south and the feeder roots of some sugarbeets that orient east-west (5, 11). East-west or north-south alignments have not been reported for sunflower roots.

Harvesting north-south rows. The heads are leaning toward the east.

Table 8. Plant spacings for five populations in rows of various widths

Plants per acre	Row width: 22 inches	30 inches	38 inches	Other* (number)
	plant spacing (inches)			
15,000	19.0	13.9	11.0	418
20,000	14.3	10.5	8.3	314
25,000	11.4	8.4	6.6	251
30,000	9.5	7.0	5.5	209
35,000	8.1	6.0	4.7	179

*For plant spacing in any row width, divide the number given by the row width in inches.

Table 9. Average yield, seed oil percentage, and seed size of Sputnik and Sundak grown at 24,000 plants per acre in various row-widths at Elk River and Rosemount in 1973

Row width inches	Seed yield/acre (pounds) Elk River	Rosemount	Oil* (percent)	Large seed** (percent)
14	862	2,015	41.3	30
17	936	2,084	41.3	30
19	805	1,735	40.6	29
22	883	2,176	40.6	32
24	821	1,833	40.8	29
25	912	1,879	41.3	30
27	832	2,141	40.7	31
29	716	1,909	40.7	31
30	956	1,847	40.0	32
32	794	2,039	40.4	34
33	801	1,747	40.9	33
35	786	1,964	40.3	33
36	935	2,033	40.5	—
37	947	2,196	40.5	—
38	—	1,945	—	—
40	—	2,163	—	—
LSD 5%	241	501	0.4	4

*Oven-dry basis.
**Held on 20/64 (Sundak) and 14/64 (Sputnik) round-hole screens.

The phototropic growth of sunflowers suggested that light interception and plant competition might differ in east-west and north-south rows and cause yield or lodging differences. Trials to compare sunflower performance in east-west and north-south rows were conducted with oilseed varieties (Romsun 52 and Sputnik) and nonoilseed varieties (69VI and D-694) on silt loam soil at Rosemount. Romsun 52 and 69VI were grown in 1972 and Sputnik and D-694 in 1973.

experimental details

A split-plot layout replicated six times was the plot arrangement in both 1972 and 1973. Row directions were the main plots, and varieties were subplots. The row width was 30 inches and the plant population was 19,440. Main plot size was 16 rows, each 40 feet long, and subplots were 8 rows, each 40 feet long. Yield samples consisted of 16-foot lengths of the center two rows of each subplot.

Circular planting arrangements as described on page 8 for the row-width trials were used to compare 18 different row directions of Sputnik and D-694 varieties in 1973. In contrast to the row-width plots of 180-degree arcs, these row-direction plots consisted of the 16 central plants of a "wheel-spoke". Thus each circle had 18 row-direction spokes replicated twice.

row direction comparisons

Sunflowers grown in east-west and north-south rows in large, rectangular plots did not differ in yield, oil percentage, large seed percentage, seed weight, or test weight with any variety nor on the average (table 10). But

Table 10. Row-direction effects on average yield, seed oil percentage, seed size and weight, seed test weight, and lodging of four varieties at Rosemount in 1972-73

	Row direction	
Characteristics	East-west	North-south
Seed yield/acre, pounds	1,854	1,868
Oil**, percent	37.3	37.2
Large seed†, percent	44	40
Weight/100 seeds, grams	8.0	7.9
Test weight/bushel, pounds	26.5	26.6
Lodging (1 erect, 9 flat)	2.2*	1.4*

*East-west significantly more than north-south at the 1% level in 1972 and 5% level in 1973.

**Oven-dry basis.

†Held on 14/64 (oilseed) and 20/64 (nonoilseed) round-hole screens.

each of the varieties lodged more in east-west than in north-south rows, and differences were significant in both 1972 and 1973.

In the circular plantings, sunflower yields from the 36 spokes per circle showed random variation not fitting any directional pattern, and differences were not significant (CV 15%). Yields from the north-south plus its 10- and 20-degree spokes on both sides were compared with yields from the east-west plus its 10- and 20-degree spokes on both sides, and again there was no significant difference between predominantly north-south and east-west rows. Wheel-spoke alignments in circular plantings are an effective way of comparing yields of many row directions in minimum space. However, lodging is difficult to evaluate in such plantings because of lack of border plants.

Harvesting losses are sometimes slightly greater when combines approach east-west rows from the west. Some growers with combine pans 10 inches wide (suitable for all row widths in contrast with wider pans for specific row widths) found that such losses were reduced by driving diagonally across the rows. But, diagonal travel across the rows is usually precluded by the practice of hilling-up at the last cultivation. Hilling-up reduces lodging (8).

North-south rows may be slightly preferable over east-west, but row direction effect on sunflowers is not an important consideration for commercial production. For research plots, east-west rows with plot labels on the east end are often preferred, because it is easier to evaluate some plots when all heads face the viewer.

Rows at the ends of the field are usually planted at right angles to the main rows. The advantage of planting end rows first is that the inner row serves as a mark to raise and lower the planter. This helps prevent gaps or excess population. But if the soil is so loose that machinery tires will move the seed, end rows should be planted last. A greater rate of planting for end rows will offset loss of stand from machinery tires when the main rows are cultivated.

recommendations

For most markets that require large seed, a plant population of 15,000 is excellent. This should be increased to 20,000 in fields where expected yields exceed 2,300 pounds per acre. For oilseed markets, population should be 15,000 to 20,000 on sand or on soils with sandy subsoils within 18 inches of the surface; 20,000 to 25,000 on silt loam, clay, or irrigated sandy soils; and 25,000 to 35,000 on fields where expected yields exceed 2,700 pounds per acre. Grower experience in an area should be considered.

Cultivated row-widths in the range of 22 to 38 inches are relatively unimportant, but lodging is worse in wide rows.

Good quality seed of small or medium size gives greater percent emergence and costs less per acre than large seed.

Plants in north-south rows lodge less than those in east-west rows, but shape of the field and erosion control are more important factors in choosing row direction. It is usually best to plant end rows first.

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